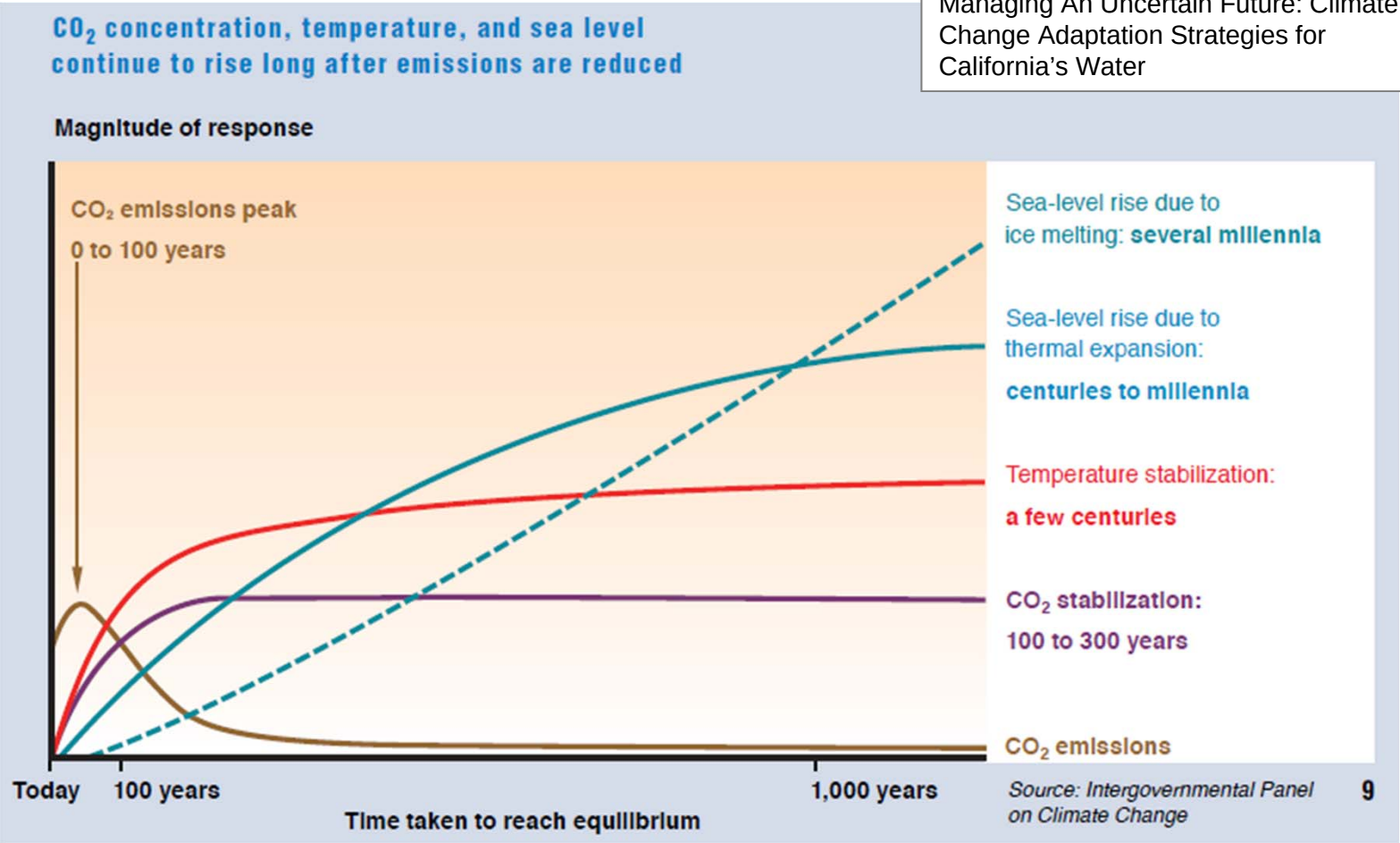
Adaptation Planning

- The "adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities" (IPCC, 2007).

Managing An Uncertain Future: Climate Change Adaptation Strategies for California's Water



Navy/DoD Recognition of Need to Plan for Climate Change

- **2010 Quadrennial Defense Review:** Complete a comprehensive assessment of all installations to assess the potential impacts of climate change on its missions and adapt as required.
- **Navy Task Force Climate Change** - Climate Change Roadmap signed by VCNO in May 2010: Action Item 3.1 Initiate a Navy Climate Change Adaptation Capabilities Based Assessment.
  - The impact of changing precipitation and weather patterns on installations, including environmental stewardship efforts, land use, and water management
  - Current and required capability of infrastructure to adapt to climate change, with particular emphasis on sea level rise and impacts on installations' natural and cultural resources
- **2011 Naval Studies Board** - National Security Implications of Climate Change for U.S. Naval Forces: Address naval coastal installation vulnerabilities due to anticipated sea level rise and storm surges.

Navy Task Force Climate Change

Establishment

Chief of Naval Operations
Executive Board on May 15, 2009

Composition

Navy, NOAA, USCG in core group with
Joint, interagency, international support

Charter

Global climate change impacts

NAVY
Task Force
Climate Change

Rear Admiral Dave Titley
Director, Task Force Climate Change /
Oceanographer of the Navy

Navy Task Force Climate Change

Near-term

- Increasing Arctic maritime activity
- Partnership opportunities
- Energy security initiatives

Mid-Term

- Sea level rise impact on installations
- Water/resource challenges
- Potential increase in HA/DR

Wild-cards

- Ocean acidification
- Abrupt climate change
- Geoengineering

Recent/Ongoing Research and Studies

- DoD Strategic Environmental Research Development Program (SERDP):
  - Naval Station Norfolk, Virginia
  - Eglin Air Force Base, Florida
  - Marine Corps Base Camp Lejeune, North Carolina
  - Marine Corps Base Camp Pendleton and Naval Base Coronado, California
- NAVFAC Engineering Service Center: 2009 inundation study in support of the QDR
- DoD Strategic Sustainability Performance Plan (SSPP): 2010 North Carolina Study
- Center for Naval Analyses: DoD Climate Change Adaptation Planning
- Noblis: 2010 Climate Change Planning for Military Installations

Strategic Environmental Research and Development Program

- 2009 SERDP Statement of Need: Assessment Of The Impact Of Sea Level Rise On Military Infrastructure
  - Develop analysis methods to assess the impacts of local mean sea level rise of 0.5, 1.0, 1.5 and 2.0 meters on U.S. military infrastructure
  - Include an assessment of the potential impacts caused by an increase in the frequency and intensity of storms.
  - The physical effects of sea level rise to be examined include, but are not limited to:
    - inundation of land,
    - increased storm and flood damage,
    - loss of wetlands,
    - changes in erosion patterns and rates,
    - salt water intrusion in surface and ground waters,
    - rising water tables, and
    - changes in tidal flows and currents.

A Methodology for Assessing the Impact of Sea Level Rise on Representative Military Installations in the Southwestern US

Dr. Bart Chadwick, PI - SPAWAR Systems Center Pacific

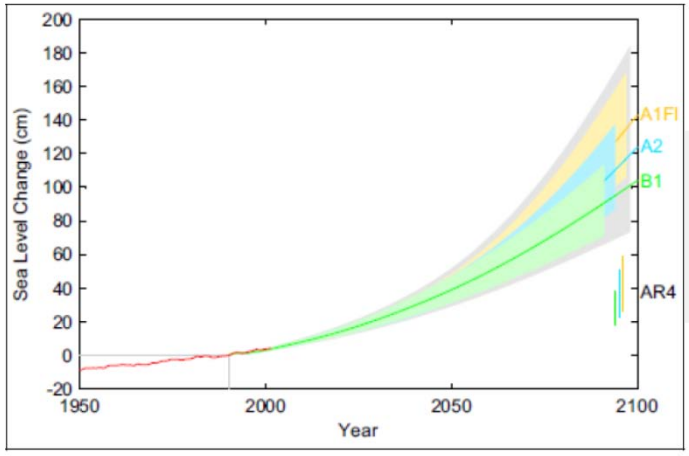
Dr. Reinhard Flick – Scripps Institution of Oceanography

Dr. John Helly – UCSD: San Diego Supercomputer Center

Dr. Walter Oechel – SDSU: Global Change Research Group

Dr. Tracy Nishikawa – US Geological Survey

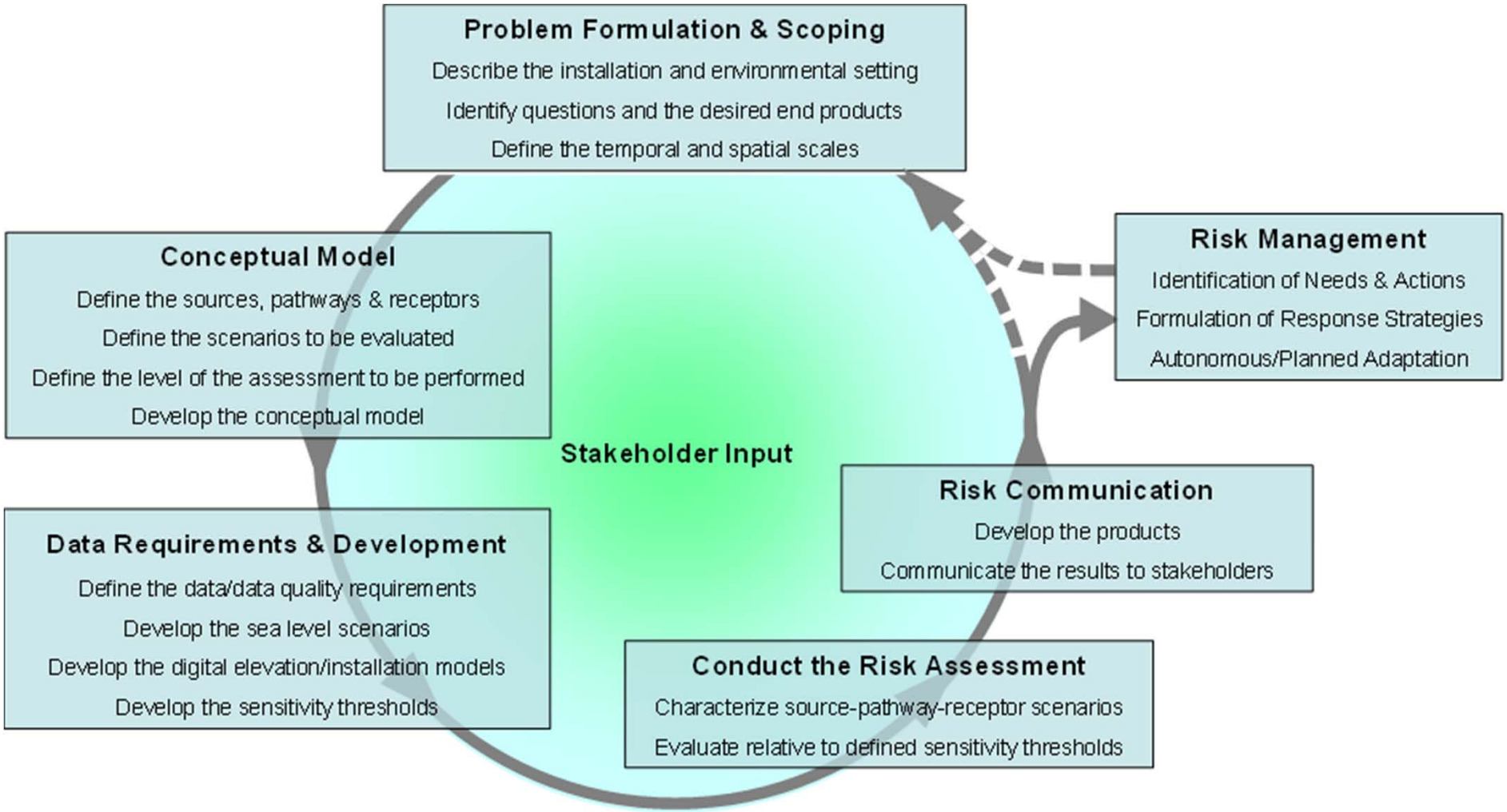
Mr. Issac Canner – Moffatt/Nichol Blaylock



Focus on Naval Base Coronado and MCB Camp Pendleton

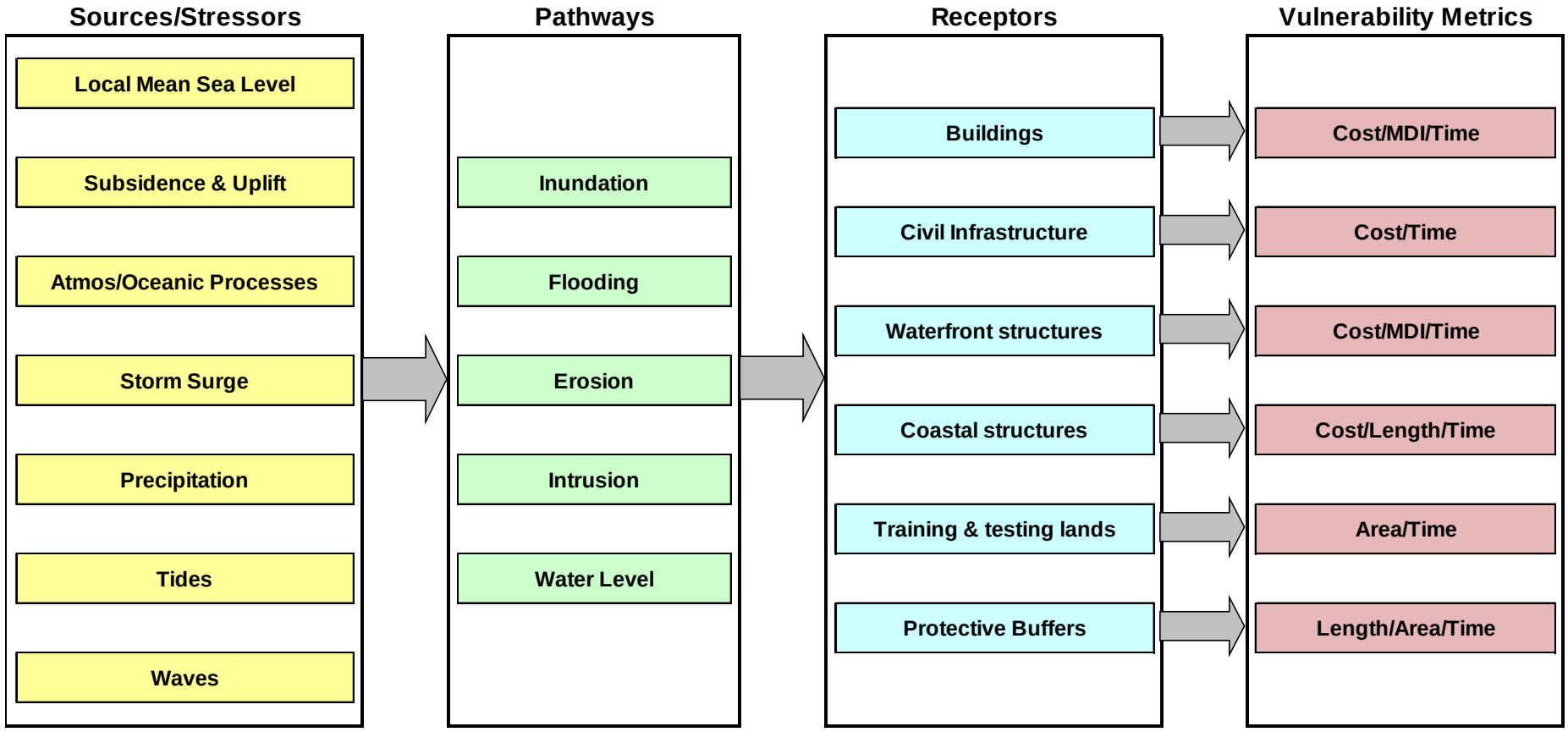
Vulnerability Framework

- Vulnerability assessment and adaptation are iterative



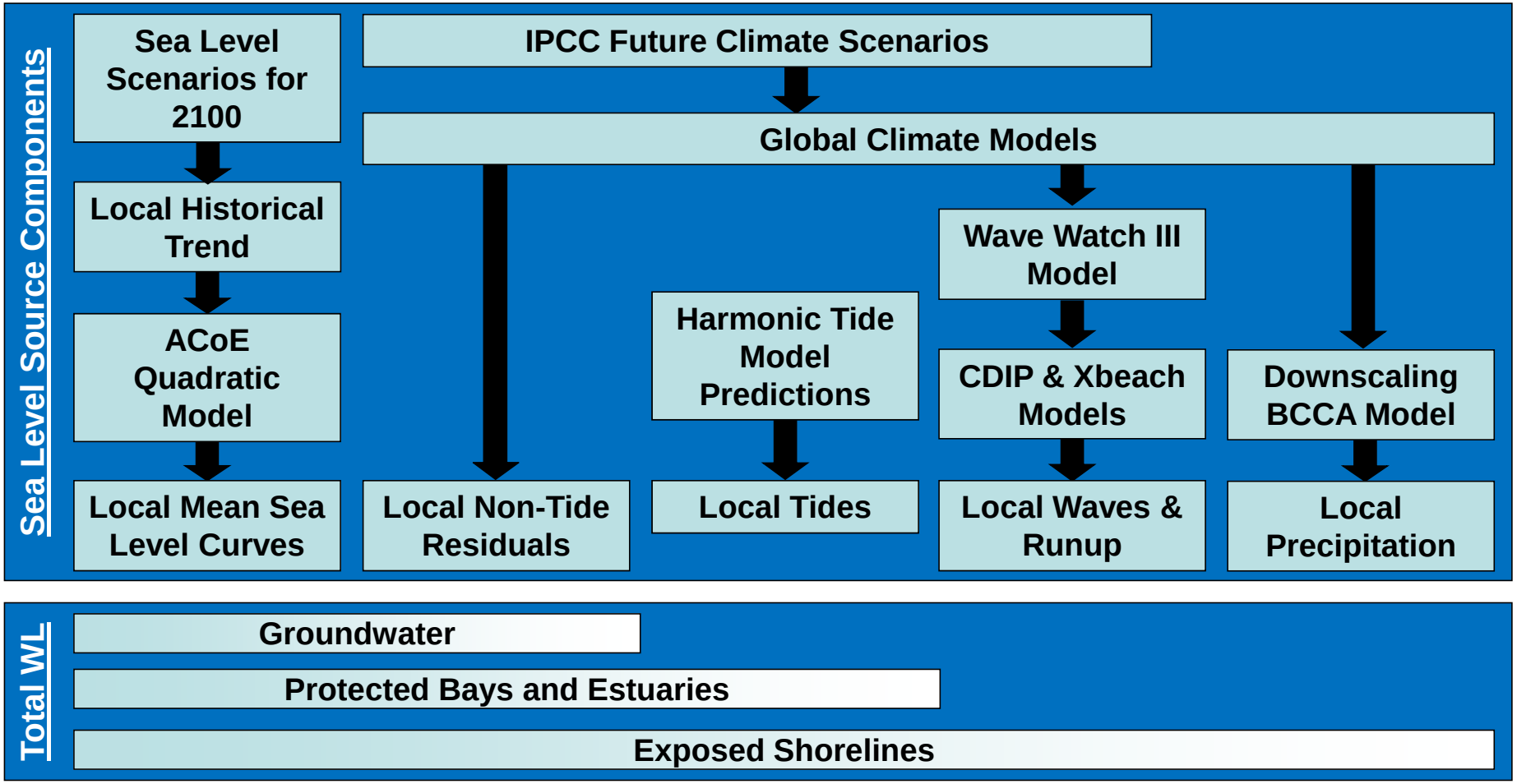
Vulnerability Framework – Conceptual Model

- Climate vulnerability is complicated!
- To be more useful, our assessments need to be more quantitative



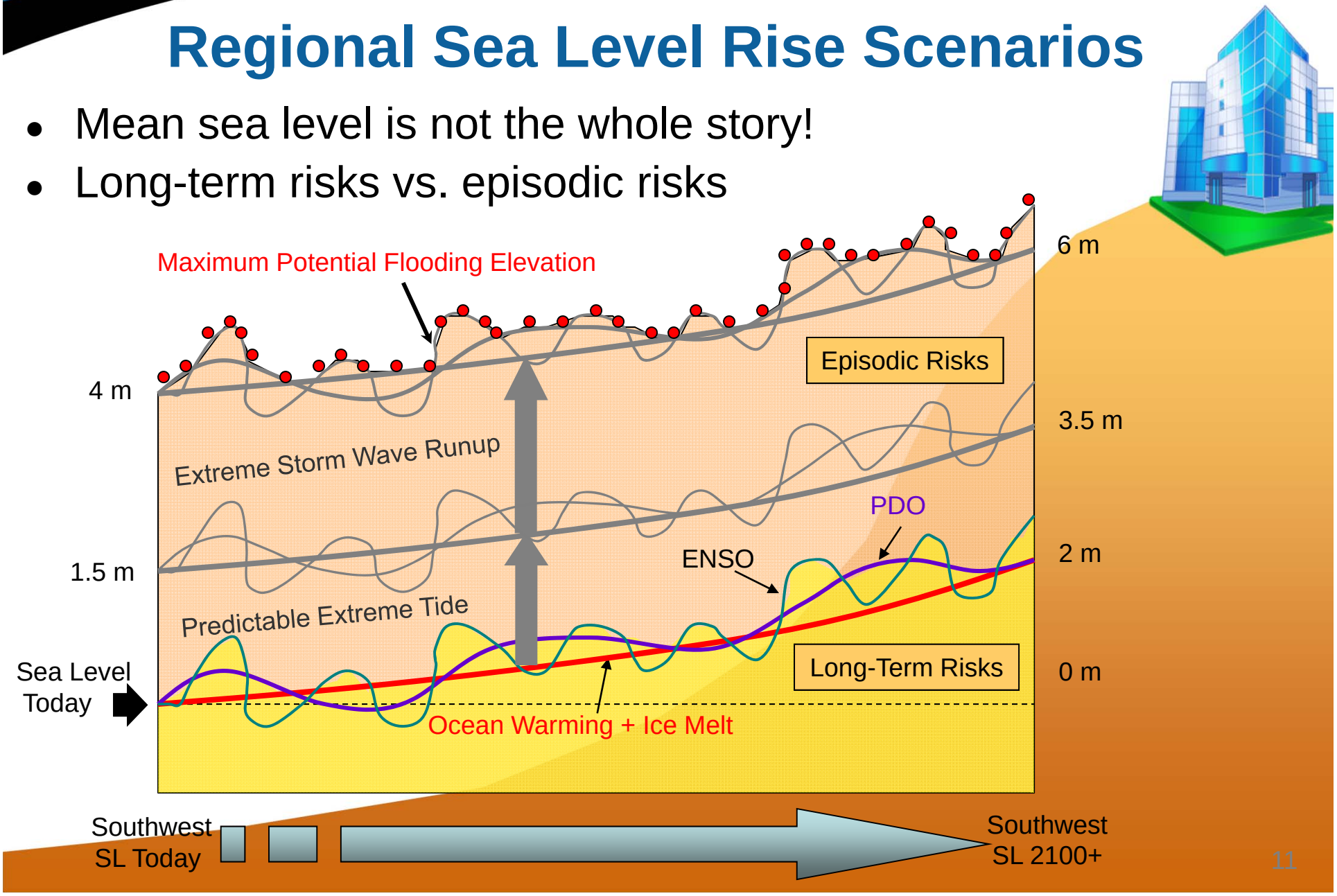
Regional Sea Level Rise Scenarios

- Mean sea level and sea level variability linked to future climate!



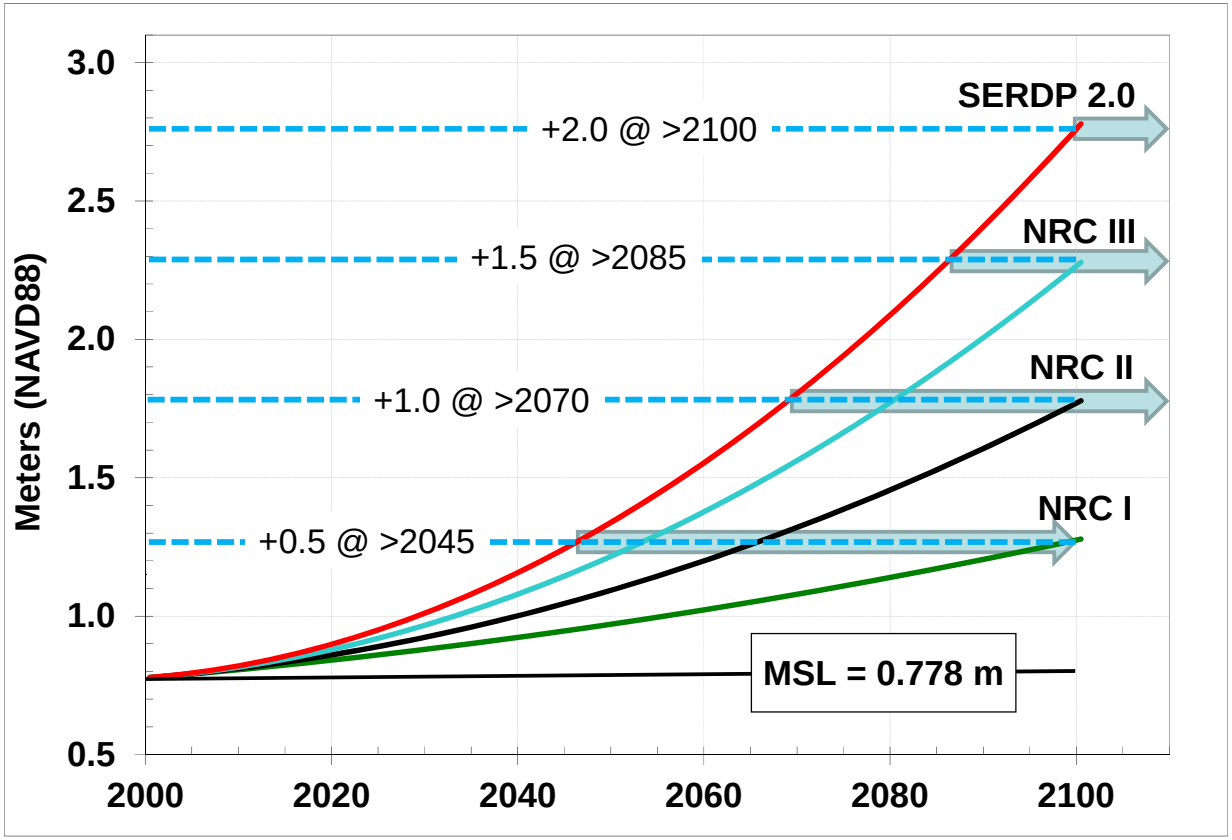
Regional Sea Level Rise Scenarios

- Mean sea level is not the whole story!
- Long-term risks vs. episodic risks



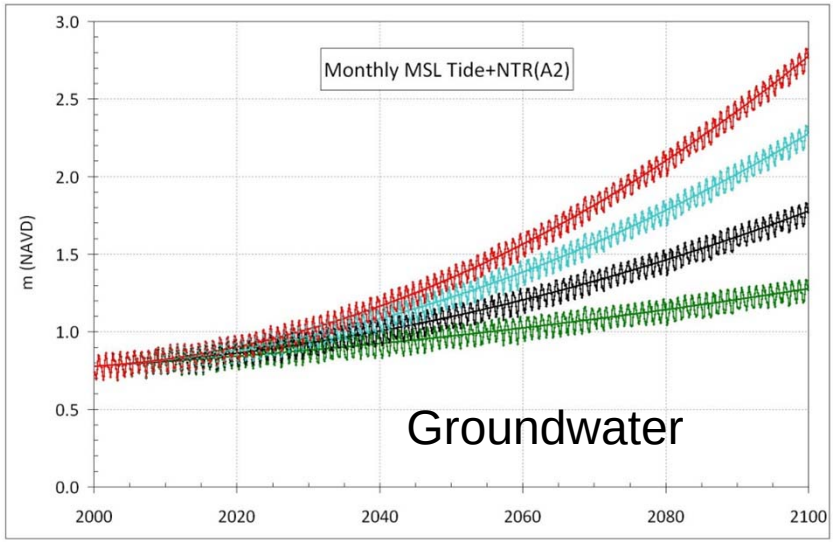
Sea Level Scenarios – Mean Sea Level

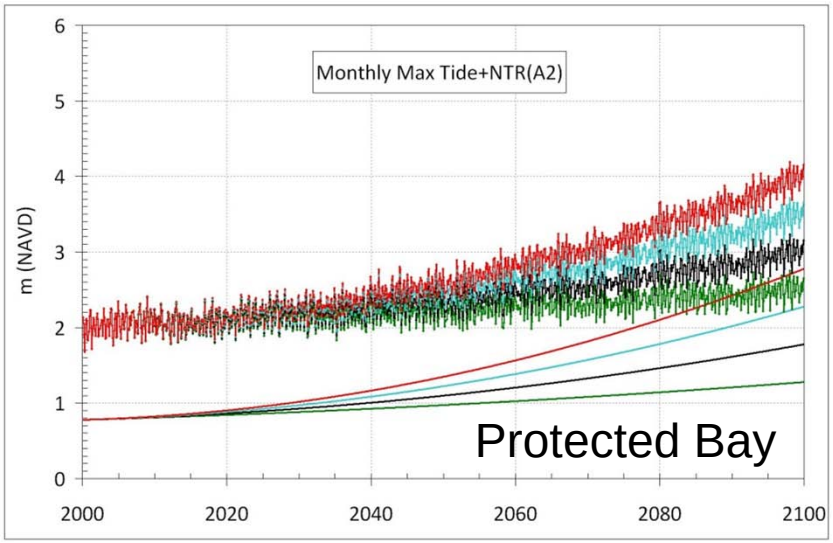
- Depending on uncertain scenarios, increased sea level conditions may occur at different times in the future

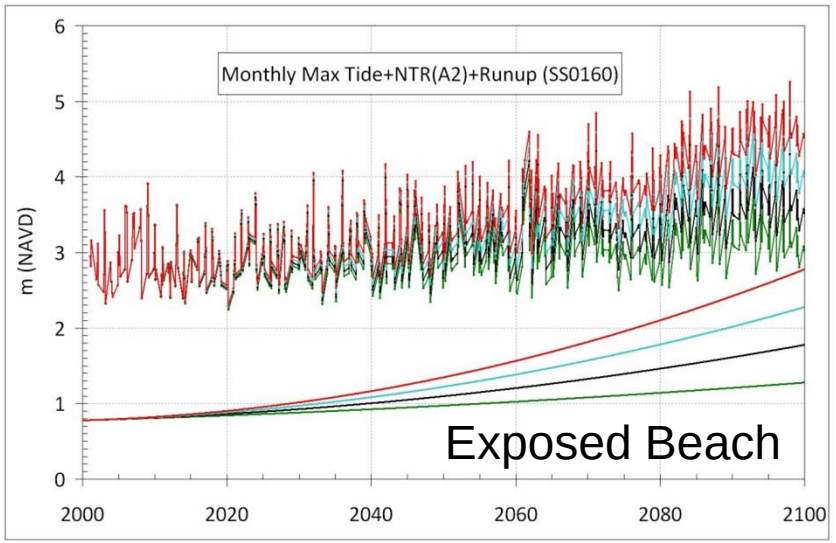


Sea Level Scenarios - Combined

- Future sea level conditions depend on the exposure







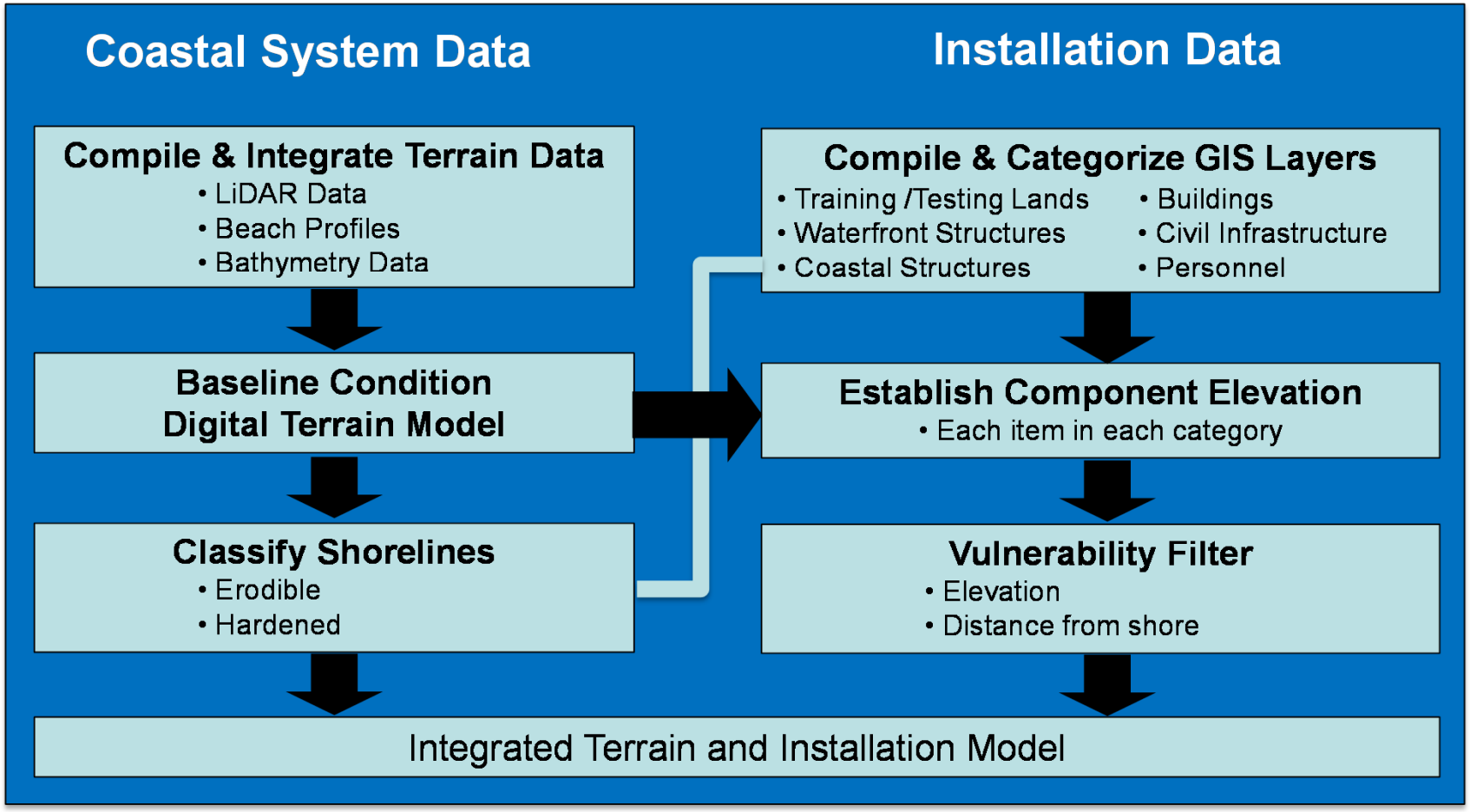
Sea Level Scenarios – Scenario Matrix

- Increasing sea level results in the progression of rare events toward common events!

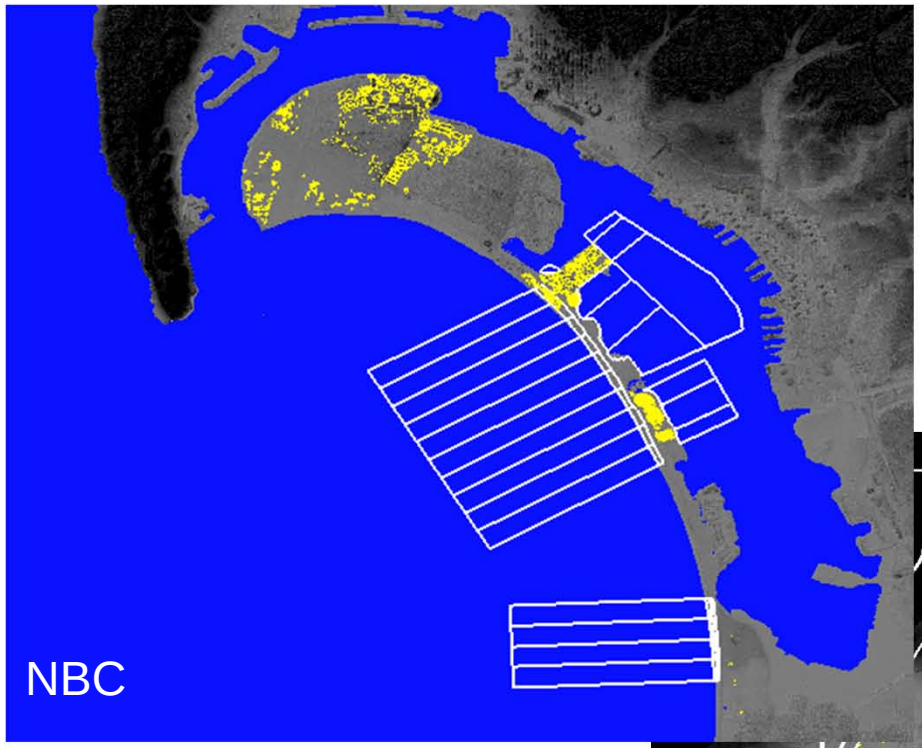
Location/ Condition	Rerurn Period	Baseline (m NAVD)	Future MSLR (m)			
			0.5 >2045	1.0 >2070	1.5 >2085	2.0 >2100
MCBCP PN1110 Tide + Runup	Week	2.17	2.67	3.17	3.67	4.17
	Month	2.60	3.10	3.60	4.10	4.60
	Year	3.22	3.72	4.22	4.72	5.22
	Decade	3.67	4.17	4.67	5.17	5.67
	Century	4.04	4.54	5.04	5.54	6.04
NBC SS0160 Tide + Runup	Week	2.31	2.81	3.31	3.81	4.31
	Month	2.73	3.23	3.73	4.23	4.73
	Year	3.31	3.81	4.31	4.81	5.31
	Decade	3.74	4.24	4.74	5.24	5.74
	Century	4.07	4.57	5.07	5.57	6.07

Delineation of the Coastal System

- Defines the sensitivity of the installation
- Forms the baseline for change modeling

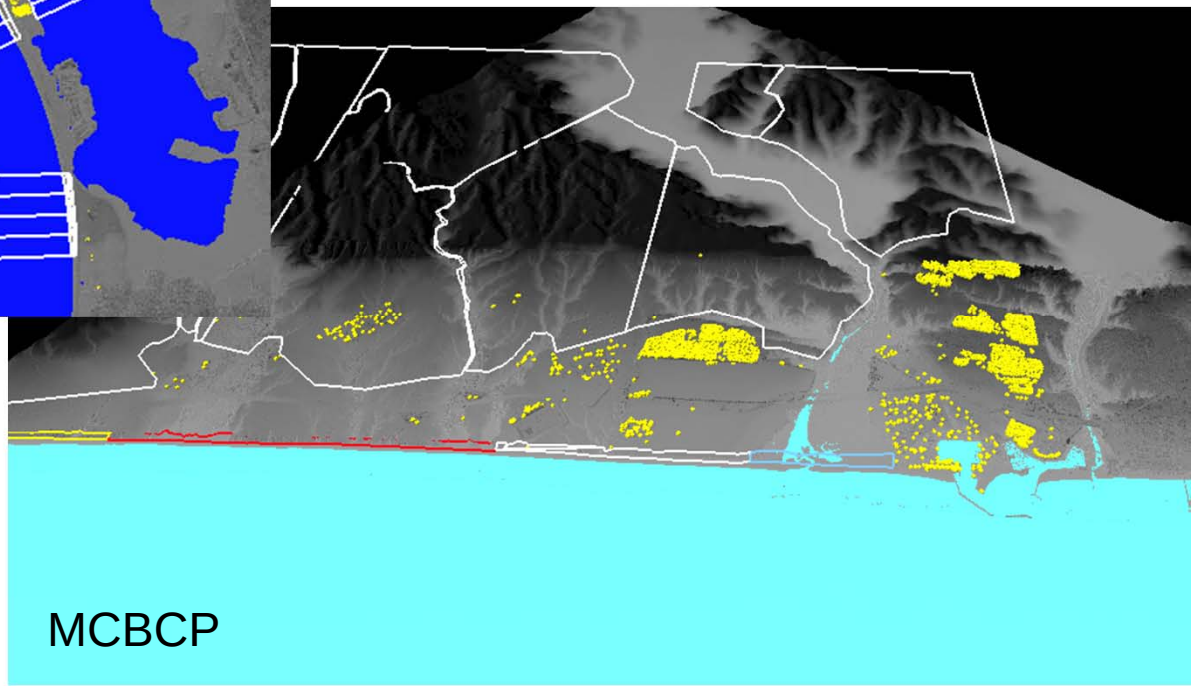


Coastal System – Terrain & Installation Models



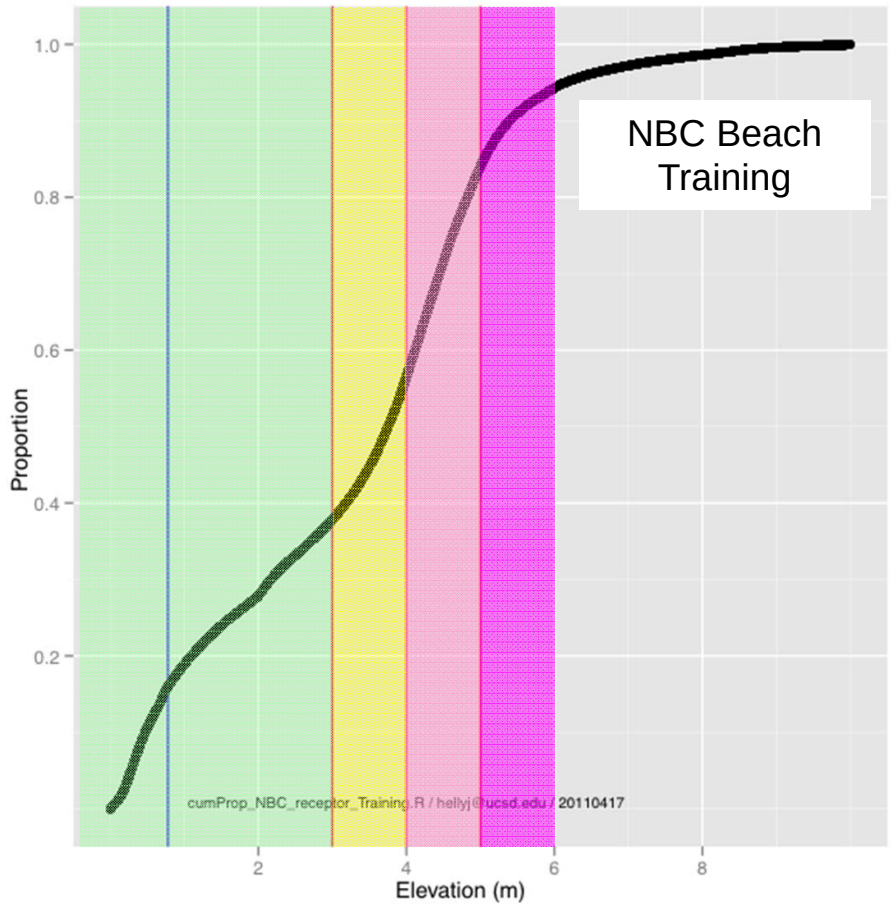
- Integrate upland, shoreline, and offshore data into a common elevation model
- Form baseline condition for shoreline change models

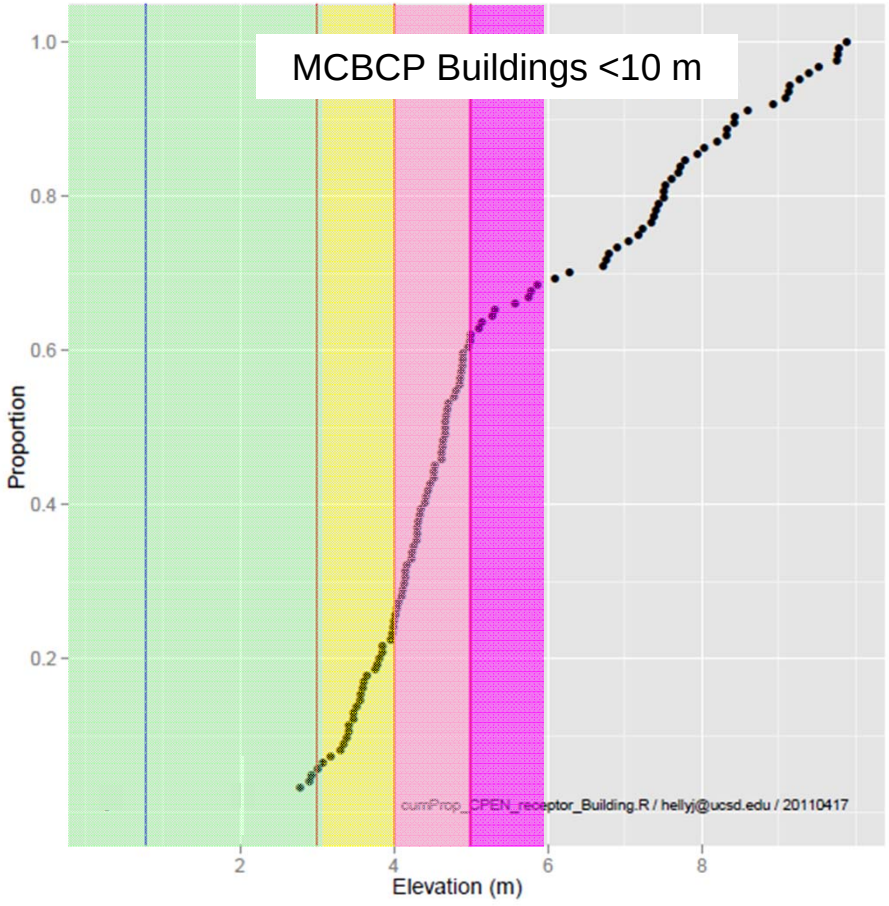
- Classify installation infrastructure
- Integrate with elevations



Coastal System – Sensitivity Curves

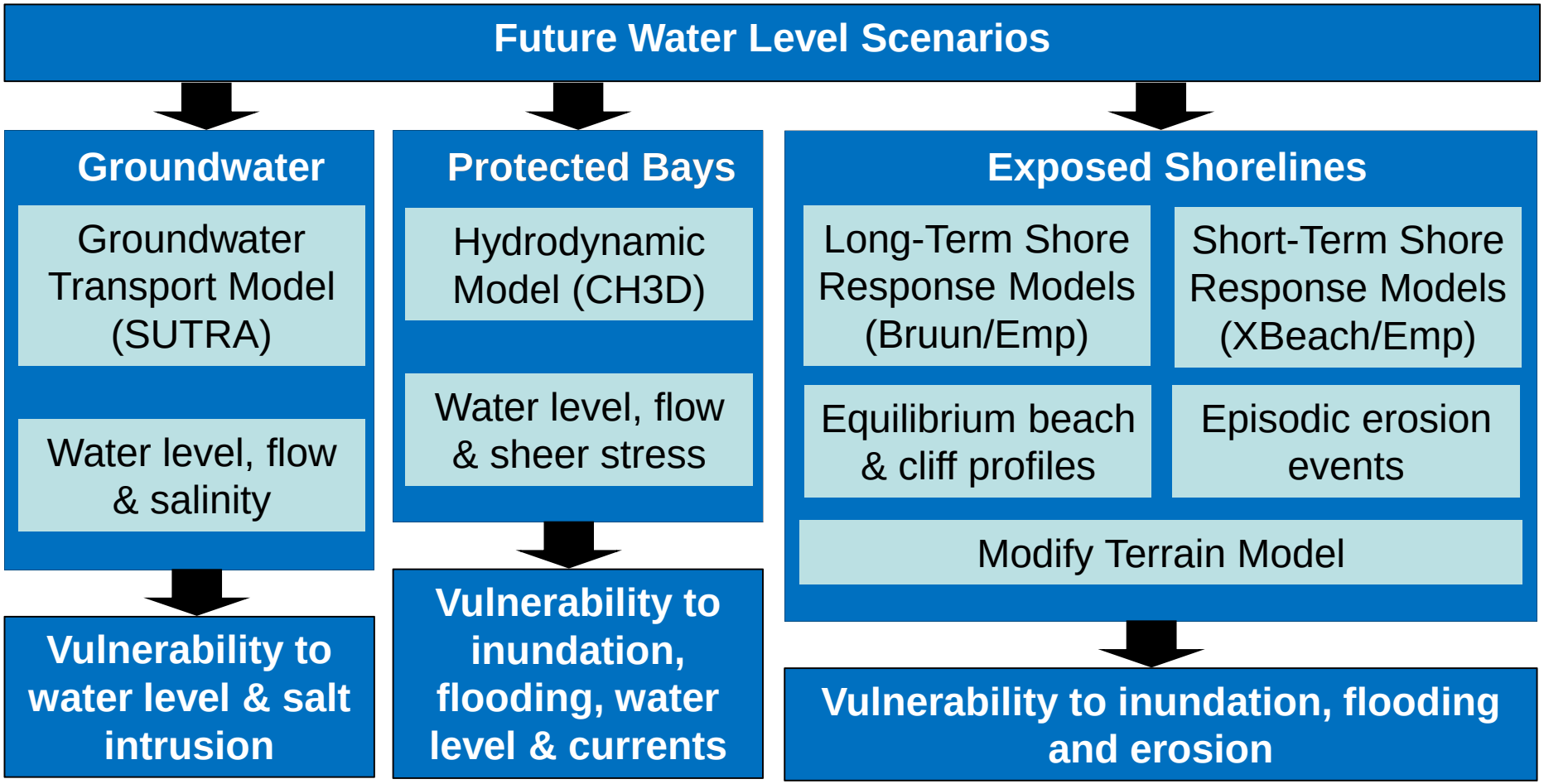
- Sensitivity is a function of the receptor
- Different receptors have different sensitivities!





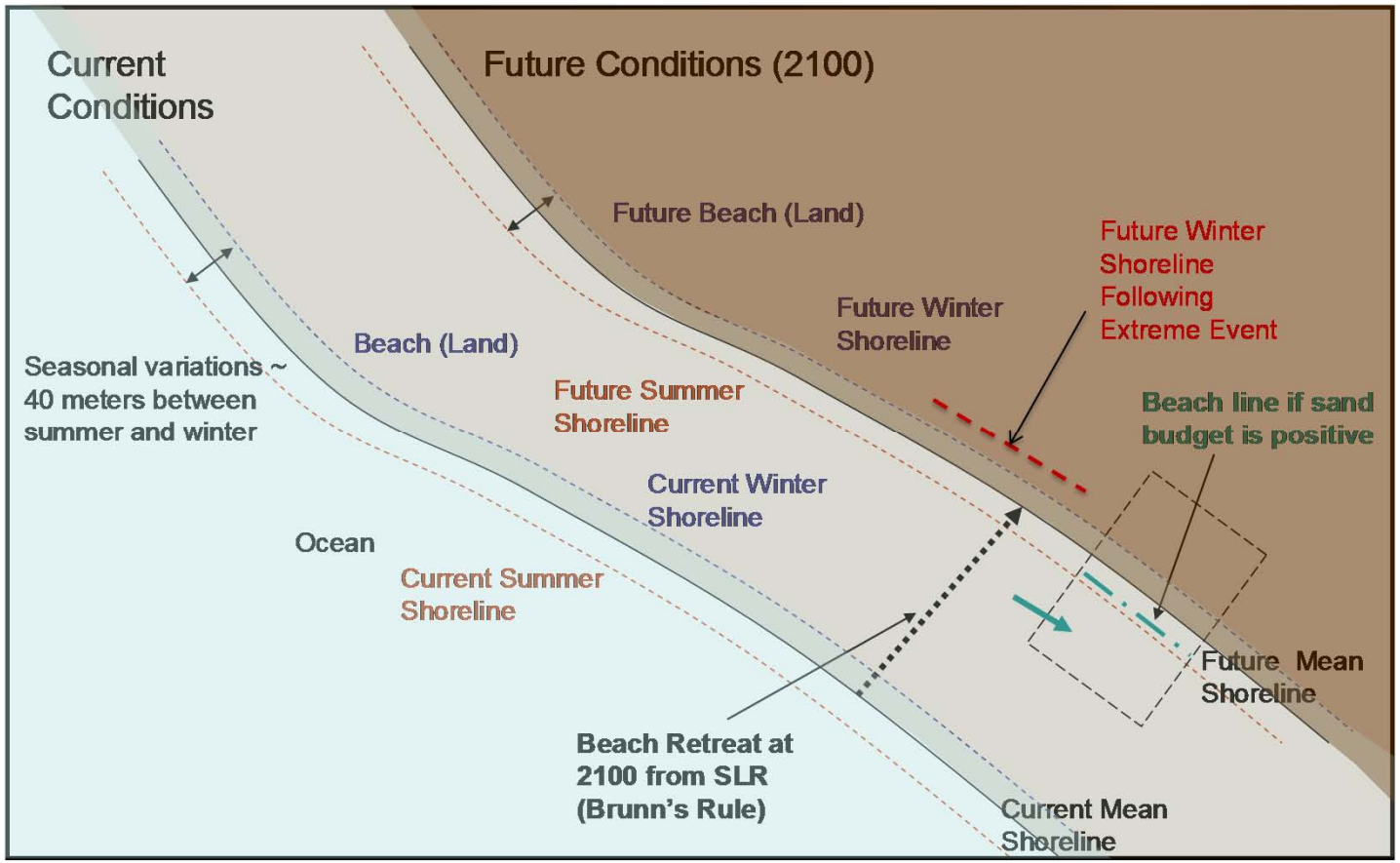
Assessment of Physical Effects

- How will the coastal system respond to changing sea level?



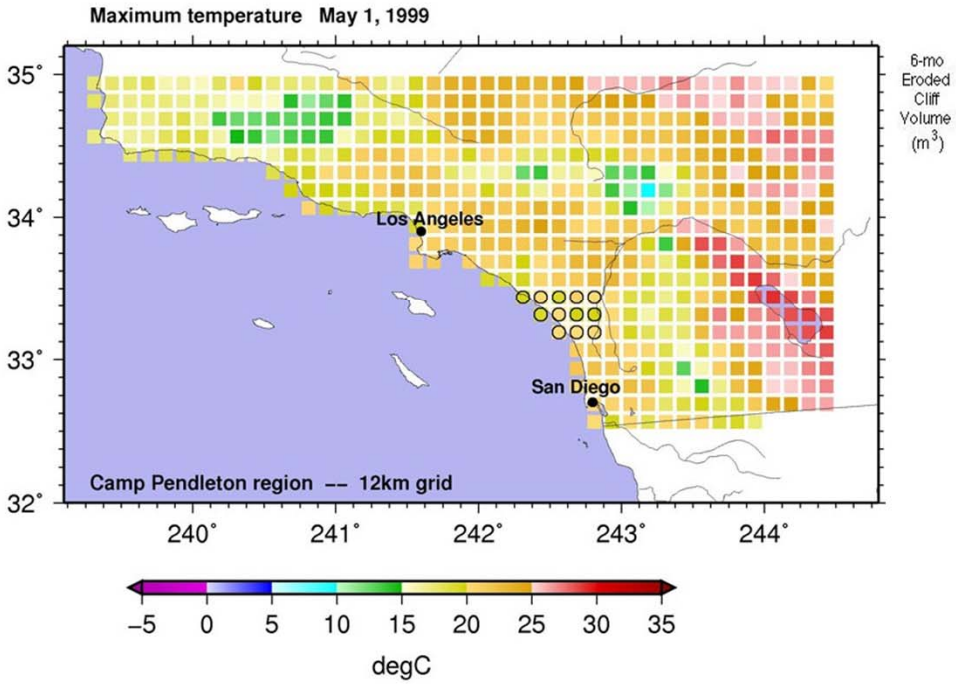
Physical Effects - Exposed Shorelines

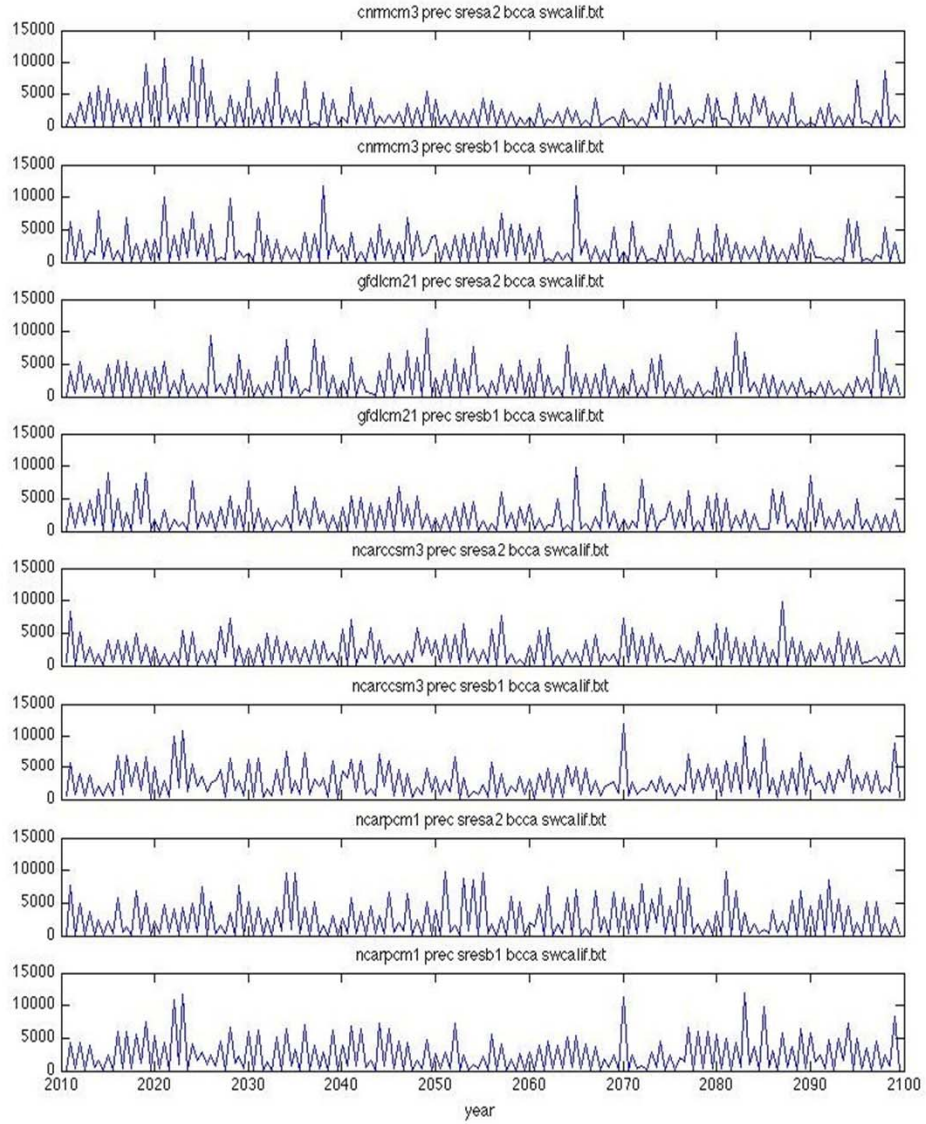
- Beach changes from combined effects of sea level rise, wave climate, and extreme storm events



Physical Effects - Exposed Shorelines

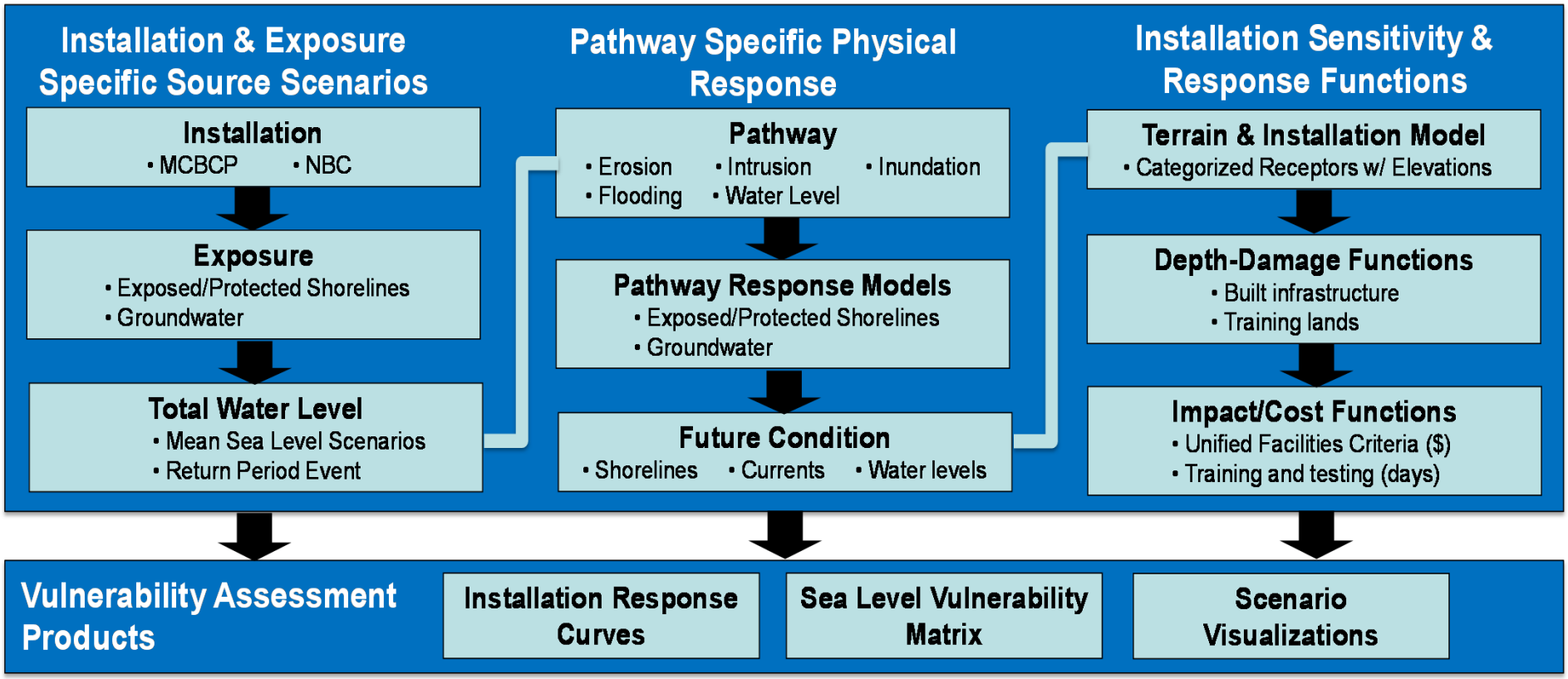
- Cliff erosion under combined effects of precipitation and wave driven erosion





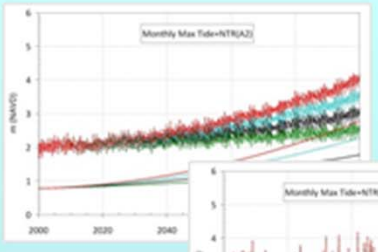
Assessment of Vulnerability

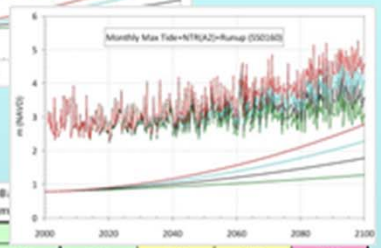
- Integrate installation scenarios with responses
- Assess vulnerability for the range of scenarios, return periods and time windows



Assessment of Vulnerability

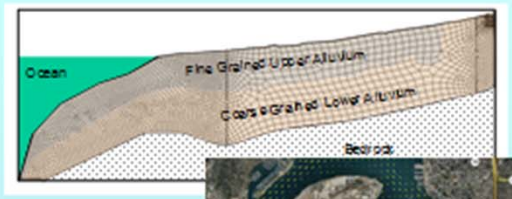
Installation & Exposure Specific Source Scenarios

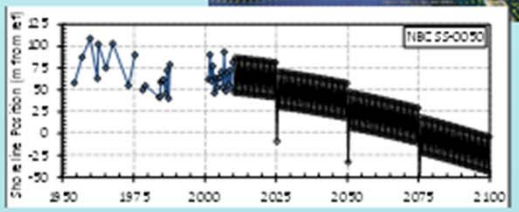




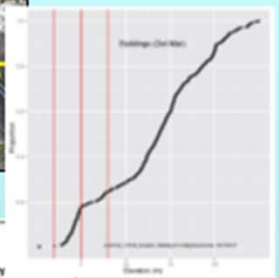
Location/ Condition	Return Period	B (m)				
MCBCP PN1110 Tide + Runup	Week					
	Month	2.60	3.10	3.60	4.10	4.60
	Year	3.22	3.72	4.22	4.72	5.22
	Decade	3.67	4.17	4.67	5.17	5.67
	Century	4.04	4.54	5.04	5.54	6.04
NRC SS0160 Tide + Runup	Week	2.31	2.81	3.31	3.81	4.31
	Month	2.73	3.23	3.73	4.23	4.73
	Year	3.31	3.81	4.31	4.81	5.31
	Decade	3.74	4.24	4.74	5.24	5.74
	Century	4.07	4.57	5.07	5.57	6.07

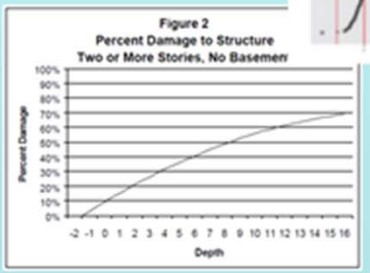
Pathway Specific Physical Response



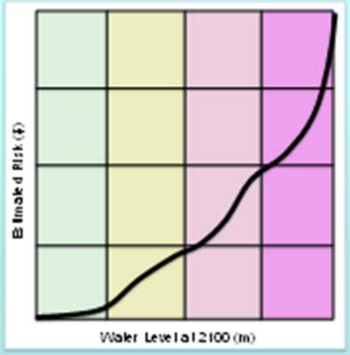


Installation Sensitivity & Response Functions



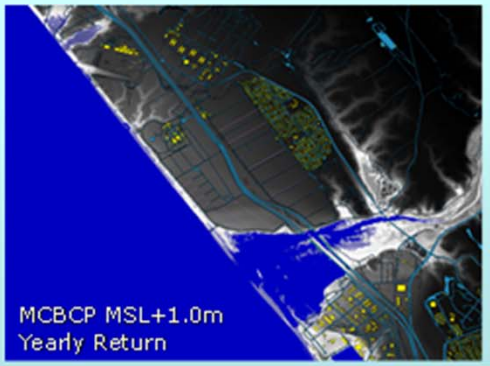


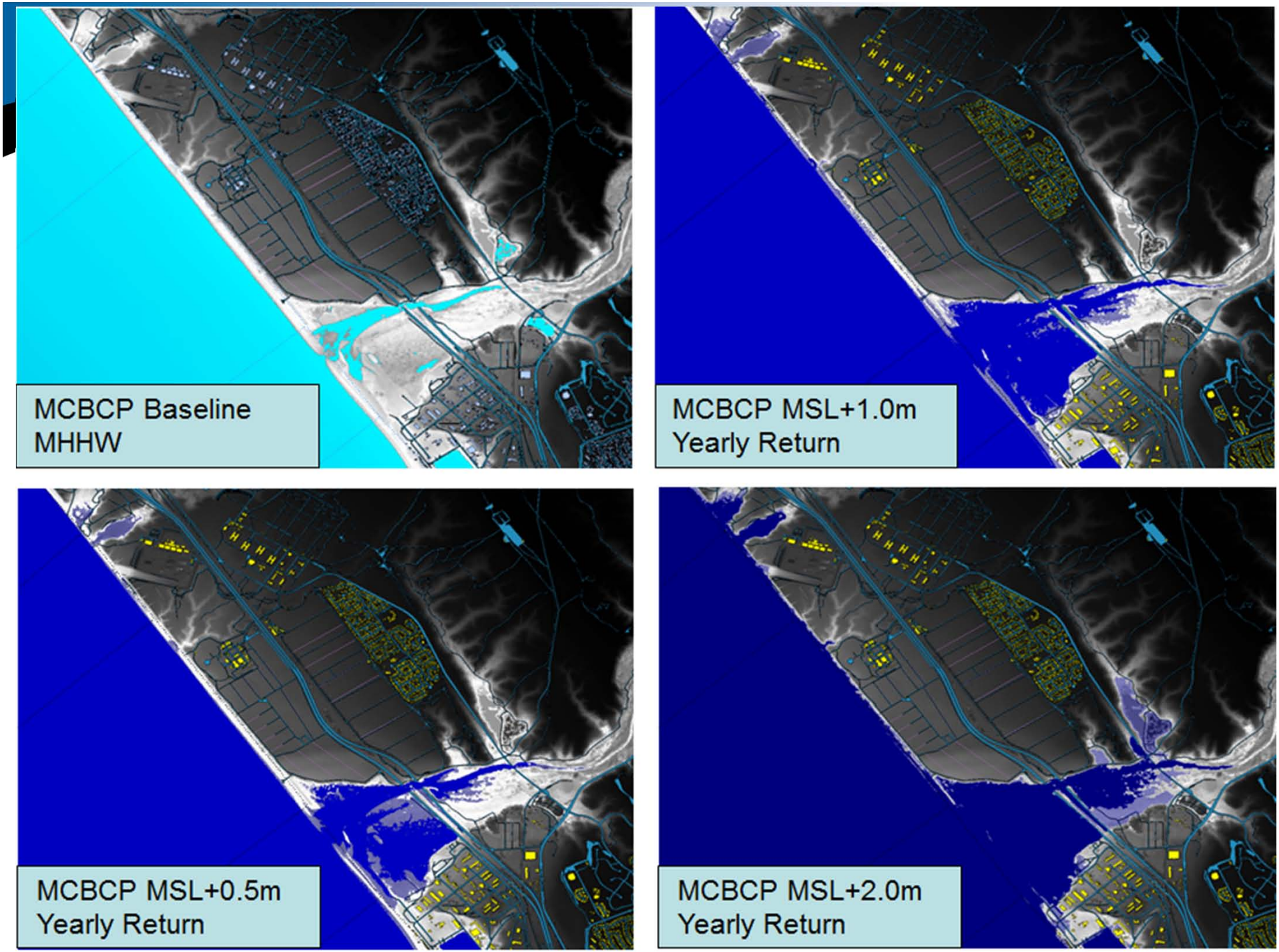
Vulnerability Assessment Products

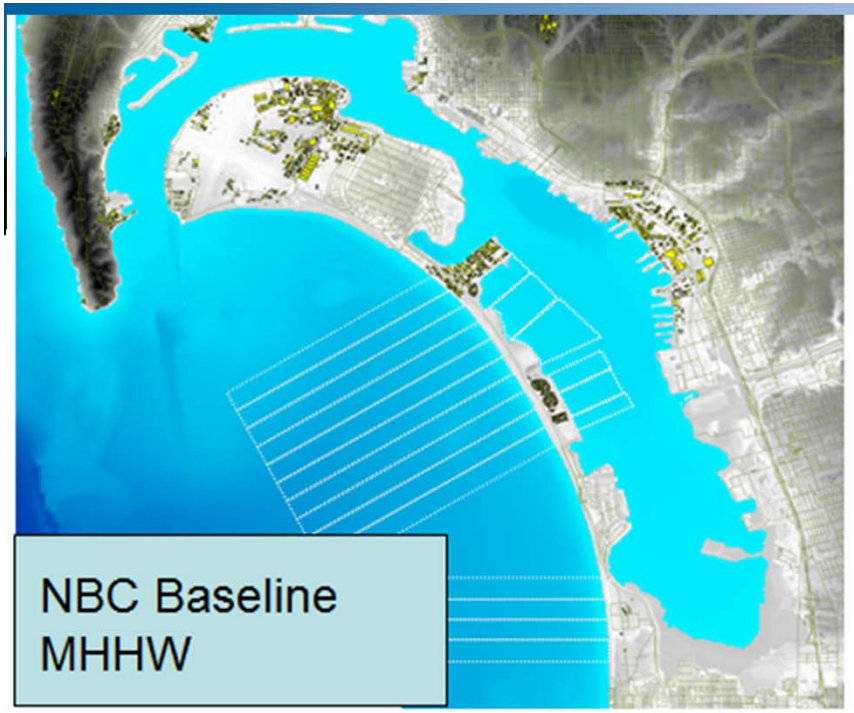


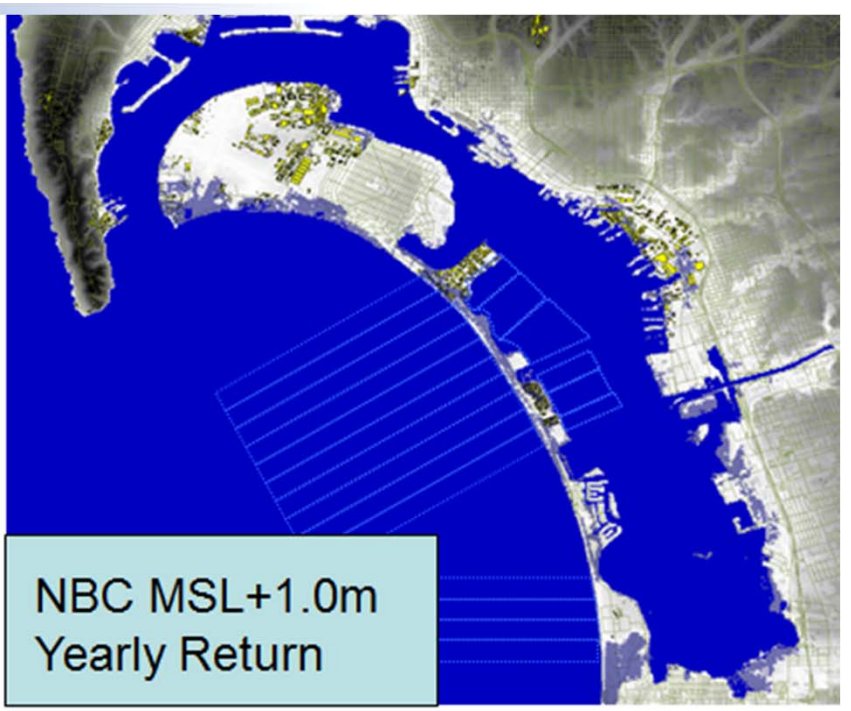
Long Term Scenario	Short Term Scenario	Receptor	Training and testing lands	Buildings	Civil infrastructure	Waterfront structures	Coastal structures	Protective Buffers
Mean SLR	Return Period	Metric	Days/Area	Cost	Cost	Days/Cost	Cost	Length
0.5 m	1 day	Estimated Risk						
	1 month							
	1 year							
	10 year							
	100 year							
1.0 m	1 day							
	1 month							
	1 year							
	10 year							
	100 year							
1.5 m	1 day							
	1 month							
	1 year							
	10 year							
	100 year							
2.0 m	1 day							
	1 month							
	1 year							
	10 year							
	100 year							

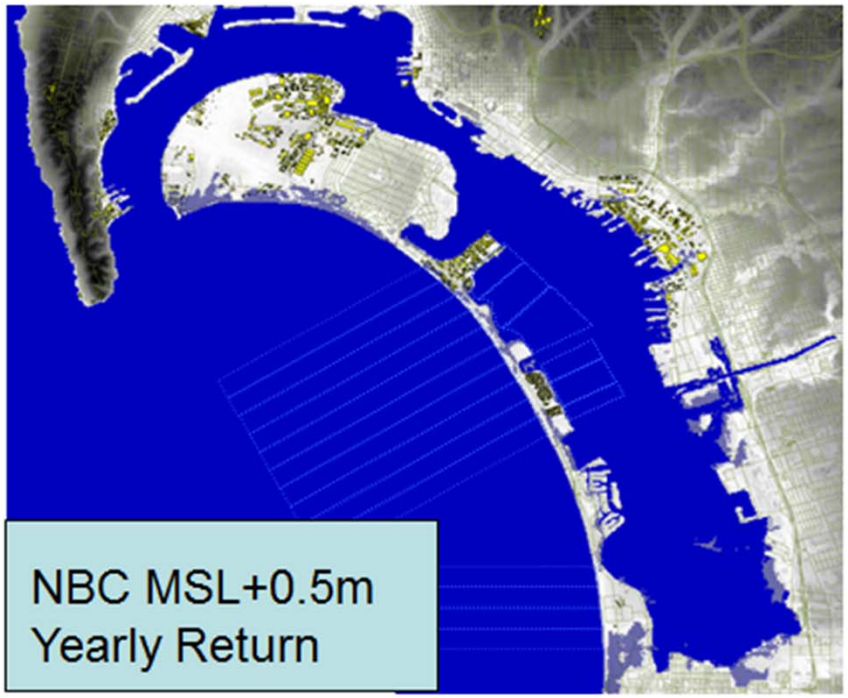
$$Risk_x = probability_x \sum vulnerabilities$$

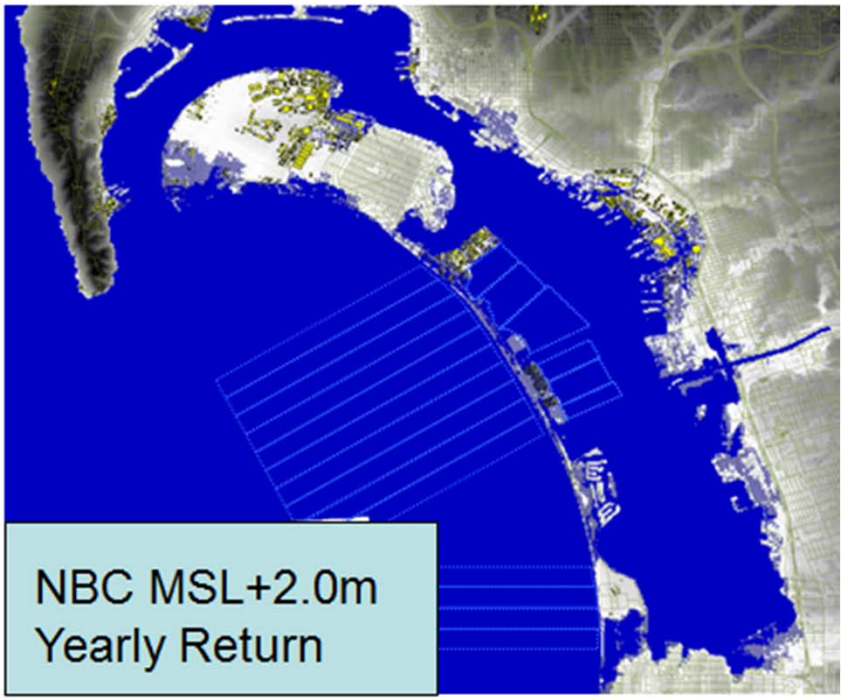



MCBCP Baseline
MHHW
MCBCP MSL+1.0m
Yearly Return
MCBCP MSL+0.5m
Yearly Return
MCBCP MSL+2.0m
Yearly Return


NBC Baseline
MHHW


NBC MSL+1.0m
Yearly Return


NBC MSL+0.5m
Yearly Return


NBC MSL+2.0m
Yearly Return

Assessment of Vulnerability

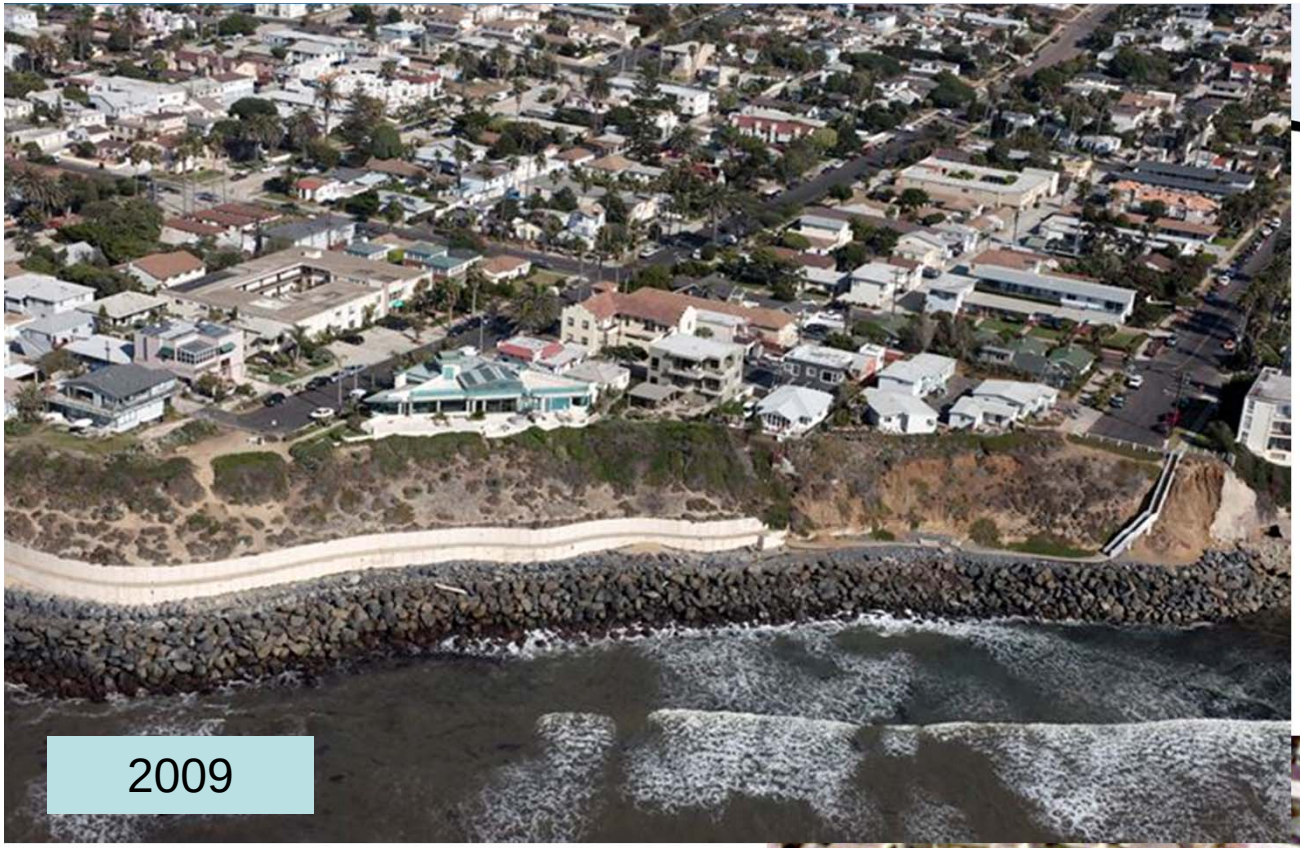
- Quantify the vulnerability based on stakeholder defined metrics
- Estimate scenario-specific risk based on the probability of occurrence combined with the associated vulnerability

Long Term Scenario	Short Term Scenario	Receptor	Traning and testing lands	Buildings	Civil infrastructure	Waterfront structures	Coastal structures	Protective Buffers
Mean SLR	Return Period	Metric	Days/Area	Cost	Cost	Days/Cost	Cost	Length
0.5 m	1 day	Estimated Risk						
	1 month							
	1 year							
	10 year							
	100 year							
1.0 m	1 day							
	1 month							
	1 year							
	10 year							
	100 year							
1.5 m	1 day							
	1 month							
	1 year							
	10 year							
	100 year							
2.0 m	1 day							
	1 month							
	1 year							
	10 year							
	100 year							

$$Risk_s = probability_s \sum vulnerabilities$$

Adaptation to Sea Level Rise

- Assess areas, infrastructure, habitat, resources and public safety at risk – communicate the risk
- Identify what areas will:
  - be sustainable under projected sea level rise
  - require shore protection
  - allow for managed retreat
- Assess the costs and benefits of potential adaptation actions considering uncertainties – engage stakeholders in decision making
- Things to consider
  - Don’t make the problem worse - Minimize development in areas at high risk
  - Protect what we have - Establish/preserve and expand natural buffers where possible
  - Minimize the impact of adaptation - Promote low impact, high habitat quality shore protection methods
  - Reduce the uncertainty for planners - Improve flood warning systems and long-term monitoring and prediction of water levels and shoreline change


2009


1972